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# LLNL Experimental Results on OMEGA: FY'04

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## LLNL Experimental Results on OMEGA: FY04

Lawrence Livermore National Laboratory (LLNL) conducted approximately 360 shots on Omega in FY04. Approximately half of the shots were devoted to ICF-relevant experiments. These are summarized as follows:

A campaign to examine the effect on a capsule of direct hydrodynamic pressure from the laser-heated fill gas in gas-filled hohlraums was begun. Initial results [Fig 1] showed that the backlit foamball surrogate gave good results at fill pressures above and below those ultimately desired. This series will continue in FY05. The interaction of a hohlraum gas fill during the hydrodynamically unstable deceleration phase was also measured; no substantial instability growth was observed, even from deliberately pre-roughened hohlraum surfaces [Fig 2].

In the area of x-ray drive, we continued to do experiments with hohlraums constructed of a mixture of materials ("cocktails"), in an effort to optimize x-ray conversion efficiency, albedo, and also laser-plasma coupling. Currently, we believe the consistently lower than expected improvement in radiation temperature for cocktail hohlraums to be due to low Z contaminants. Additional experiments were carried out to assess the performance of lined or foam-filled hohlraums, as alternates to the gas-filled NIF hohlraum point design. The early results are promising, showing radiation temperatures constant to within 5% between types of hohlraums, and low levels of backscatter with smoothed beams at  $5 \times 10^{14}$  W/cm<sup>2</sup>.

Laser-plasma interaction studies were done on large scale length plasmas created by pre-heating large gas filled targets with the main laser [Fig 3]. Various experiments, some using a 2w or 4w probe beam, were conducted, to obtain data on Raman and Brillouin scattering and beam propagation [Fig 4] as a function of beam smoothing level. The results show reduced beam spray and backscatter by using increased smoothing on a 2w probe beam. More crossing beam power transfer experiments (a form of Brillouin of special interest to NIF) were performed as a function of polarization state [Fig 5]. Thomson scattering was frequently used to measure the electron temperature of these plasmas, while backscattered light (FABS) diagnostics monitored the amount of SBS or SRS. Still other experiments demonstrated the ability to measure the time-resolved spectrum of H- and He-like Ti (5 keV) x-rays scattered by free electrons in a hot plasma; careful fits to the data yield temperature and density data [Fig 6]. Finally, a hohlraum experiment was conducted to quantify the amount of laser light which, at early times, is refracted from the hohlraum wall directly onto the implosion capsule.

We continued to make systematic improvements in using target-mounted pinholes to image implosion cores at moderately high ( $> 7$  keV) energies. Asymmetric core images were obtained at 87x magnification, demonstrating a method for measuring higher order (up to 6, possibly 8) mode structure in the hohlraum drive [Fig 7].

We obtained more data on integrated hohlraum implosions with deliberately roughened capsules [Fig 7]. These experiments were performed with convergence ratios (CR) of 15, and provide a stringent test for modeling of hydrodynamic instabilities. These same experiments demonstrated a small difference in drive asymmetry – which resulted in a degradation in neutron yield – if the presence or absence of polarization rotators was not accounted for in the laser pointing.

Ablator material studies, focusing on the Rayleigh-Taylor growth factors, continued in FY04 on polyimide and brominated plastic [Fig 8]. The results confirmed greater than expected RM growth for the thinner samples, but as-predicted RT growth rates [Fig 9]. A new more NIF-like pulse shaped, 2D symmetric gas-filled hohlraum experimental platform has been designed for August shots. We also conducted a first experiment to look at the effect of DT fill tubes on an imploded capsule, using a deposited bump on the capsule as a surrogate for the fill tube.

Building on the work on hot hohlraums (see HEDS, below), several implosion experiments were conducted using smaller-than-standard (3/4 size) hohlraums [Fig 10]. These represented the highest radiation-driven temperature implosions shot on laser facilities, reaching 275-285 eV, and producing symmetric cores. In some experiments D-He3 was used as the fuel, supplied by LLE; and D-He3 fusion proton yields and spectra were recorded and analyzed by MIT.

In collaboration with the University of Nevada, Reno (NLUF), multiple pinhole imaged and spectrally dispersed data was obtained from indirectly driven, Ar-doped fuel implosions [Fig 11].

Finally, several days of experiments were done in collaboration with LANL and LLE, using direct-drive DT filled targets, for the purpose of developing neutron diagnostics. These relatively high-yield shots have indicated that significant background will be present for any diagnostics or electronics which are neutron-sensitive.

The other half of the LLNL shots were devoted to High energy density science (HEDS)-relevant experiments. These are summarized as follows:

Hot hohlraum experiments used hohlraums which were as small as possible, to create as high as possible radiation environments. Measurements were made on effective radiation temperature, high energy (“supra-thermal”) x-rays, and laser-target coupling.

Equation of state (EOS) experiments continued on Omega in FY04. These involve VISAR measurements of shock propagation times in various materials. Other experiments focused on creating and using an adiabatic (shockless) drive [Fig 12] to smoothly ramp up the pressure for EOS measurements of solid (not melted) materials [Fig 13]. Finally, experiments done in collaboration with a NLUF investigator used gases which were pre-compressed in a diamond anvil cell, to explore equation of states relevant to the giant planets.

We also used Omega shots to explore various options for obtaining x-ray point backlighters. It is expected this knowledge will be used on future Omega and NIF shots.

A number of shots were devoted to studying alternative approaches to the standard indirect drive concept of a simple hohlraum with a single-shell capsule. These included “dynamic hohlraums”, where a high Z gas is directly driven and compressed, and its resulting x-rays are used to drive a second, concentric implosion capsule; and “double shells”, where the first, driven shell collides with an inner shell, resulting in implosion velocity multiplication.

The radiation flow campaign continued in FY04, focusing on x-ray propagation through low density foams.

A series of experiments were conducted to develop appropriate backlighter sources and detectors to measure the opacity of warm materials. The results of this campaign are expected to be used on experiments in FY05.

LLNL continued a collaboration with LANL and AWE (England) on the “Jets” experiments, looking at large scale hydrodynamic features.

Finally, we conducted shots onto gas-bag targets with various mid to high-Z gases, in connection with developing x-ray sources [Fig 14].

## Figures

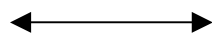
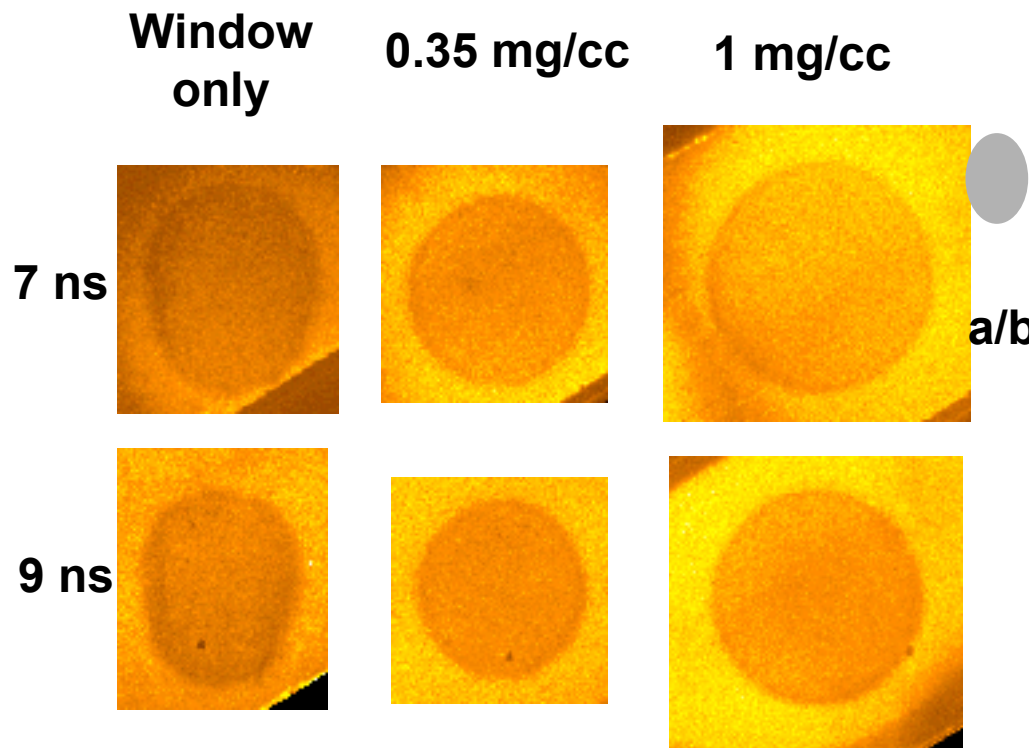
1. Backlit foam balls in CH (low radiation) gas-filled hohlraums are used to measure the gas-capsule hydrodynamic coupling.

2. End-on view of an x-ray backlit, gas-filled hohlraum, shows wall motion and stagnation, with no signs of increased mix due to surface roughness.
3. Laser-plasma interaction studies use gas-bag targets to form large, well-characterized plasmas.
4. Laser beam smoothing effectively reduces SRS in the low density plasma region.
5. Crossed beam experiments shows energy transfer under the proper plasma flow conditions.
6. Compton shifted scattered x-rays are analyzed to obtain the electron temperature.
7. Neutron yield degradation for convergence ratio (CR)15 implosions, as a function of measured capsule surface roughness. Also shown is a high magnification x-ray image of asymmetric imploded core, obtained at 8 keV.
8. Polyimide Rayleigh-Taylor experiments measure growth rate of hydrodynamic instabilities.
9. Early time RM growth rates are larger than expected.
10. Low convergence implosions in small, high temperature hohlraums were used to confirm basic drive symmetry.
11. Geometry of spectrally-dispersed imager used in NLUF experiments.
12. Experimental target set up used to produce smoothly increasing pressure drive for solid target physics.
13. R-T results for solid vanadium.
14. Ar-doped gas bag targets used to measure conversion efficiency into x-rays.

# Backlit foamballs beginning to investigate hydro coupling in NIF-scale gas-filled targets

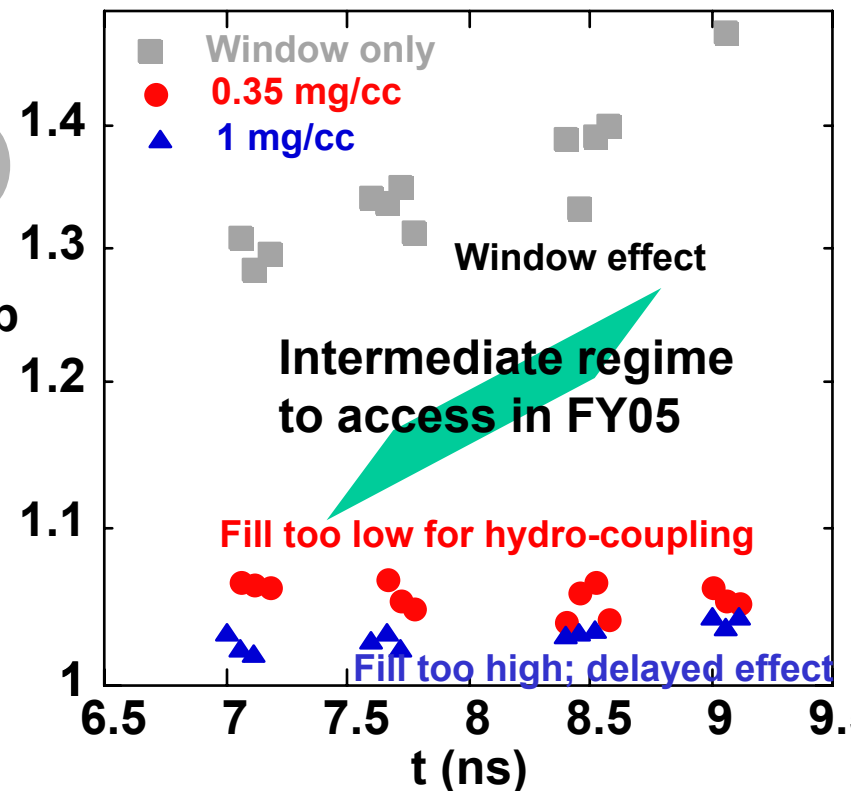
Symmetry

## 4.3 keV backlit foamball images



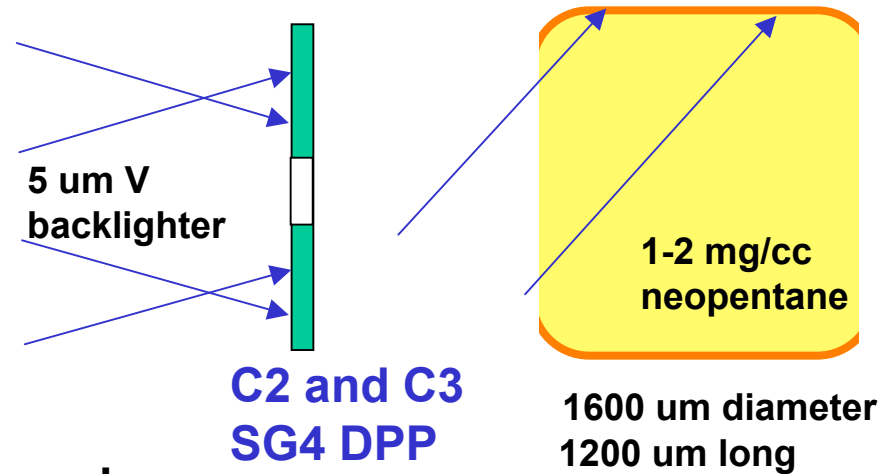
P6-P7 Hohlraum axis

## Foamball distortion vs time



Technique will be used for testing liner-capsule coupling as well

# Axially backlit radiographs of gas-filled hohlraum *Symmetry* show cylindrical roughness-independent interface



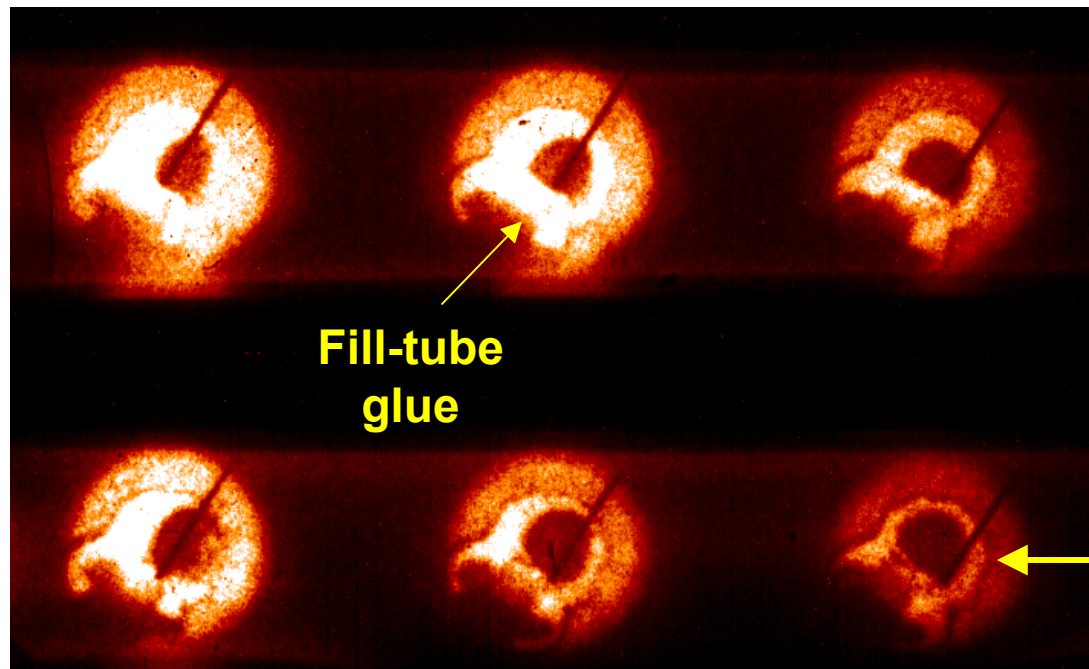
P7

Au hohlraum  
(half smooth/half rough)

Backlit radiographs

1.7 ns

1.9 ns



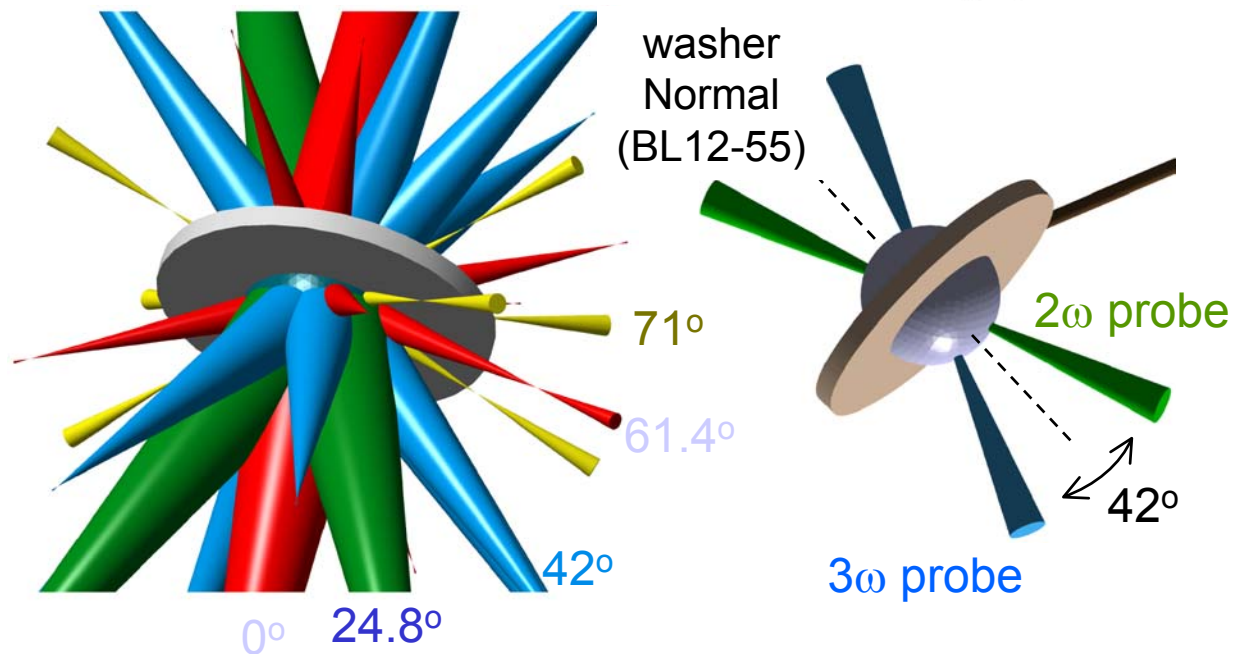
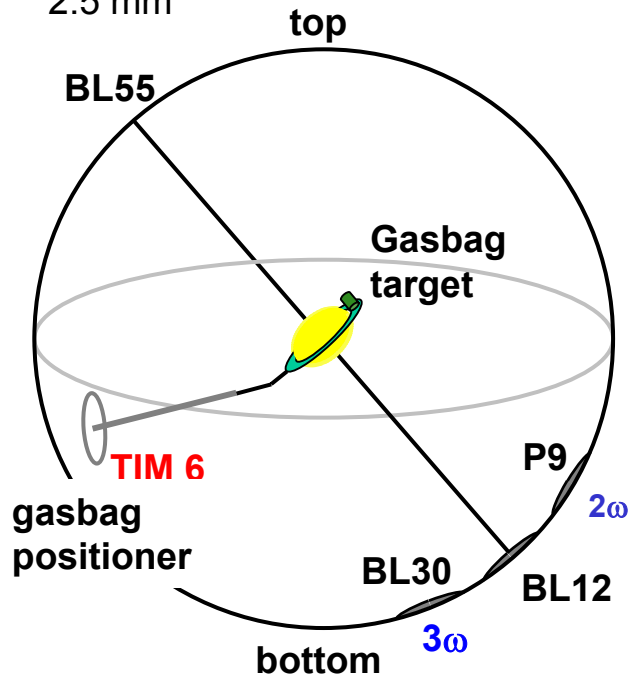
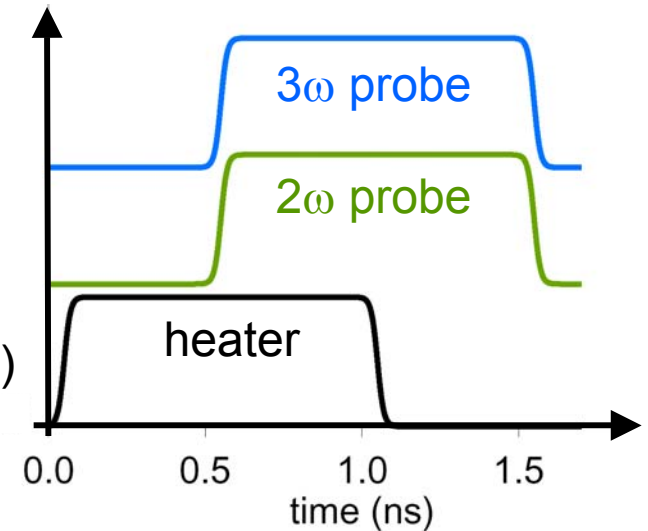
Gas-wall  
interface

# We simultaneously studied the propagation of a $2\omega$ and $3\omega$ beam through ignition relevant plasmas

gasbag

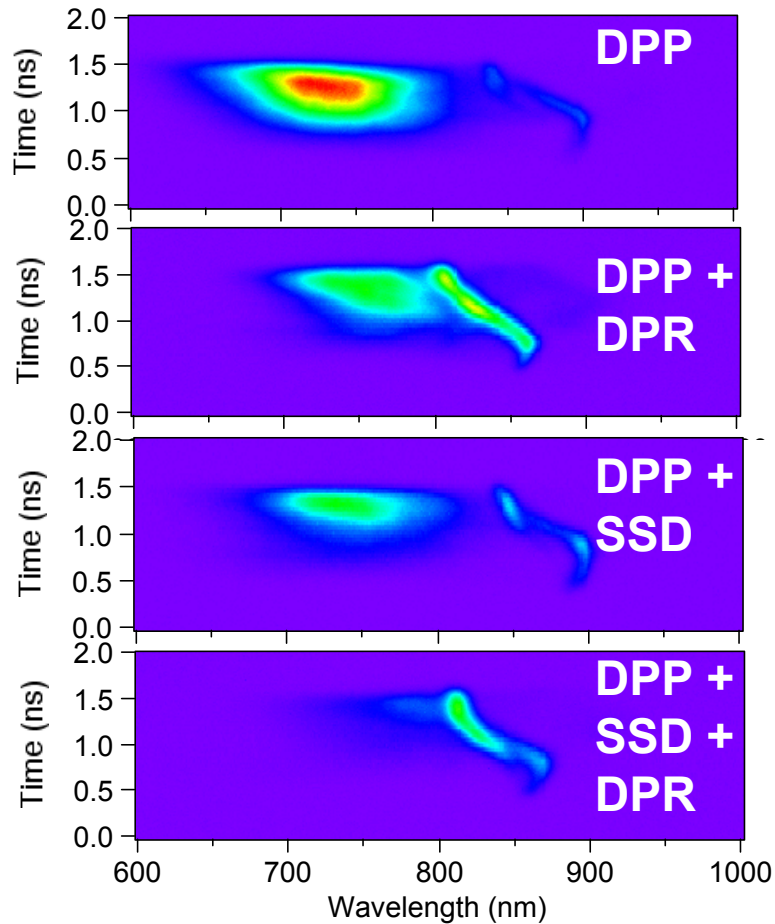


- 2 mm long CH plasma (with Ar or Xe dopant)
- 10 kJ of  $3\omega$  heater beams (36 defocused heater beams in 5 cones)
- $T_e = 1.8$  keV
- $n_e/n_c \sim 5.6\%$  @  $3\omega$  (NIF  $2\omega$  design)
- probe intensity  $10^{14}$ - $10^{15}$  W/cm<sup>2</sup> (200  $\mu$ m DPP)

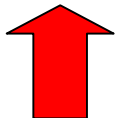


# Laser smoothing effectively suppresses the broad 2w SRS in the laser blow-off region

2 $\omega$  SRS spectra for  $I \sim 8 \times 10^{14}$  W/cm<sup>2</sup>

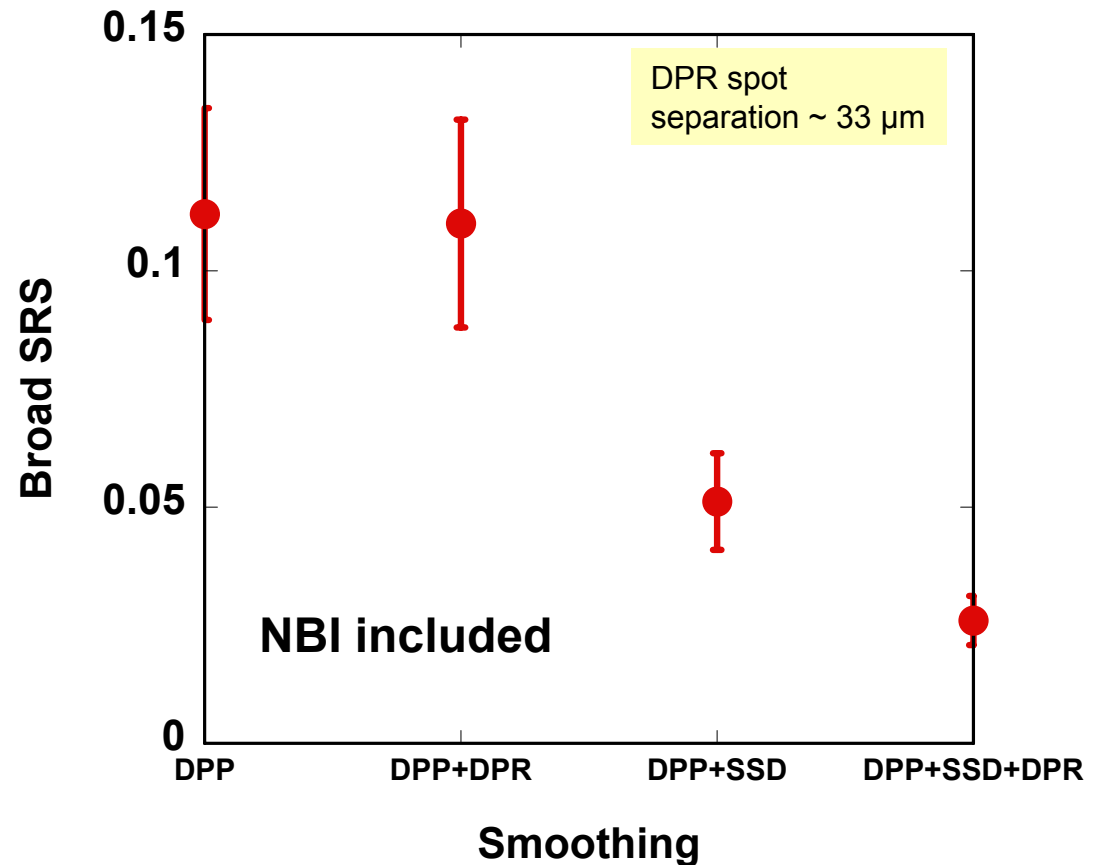


Broad SRS

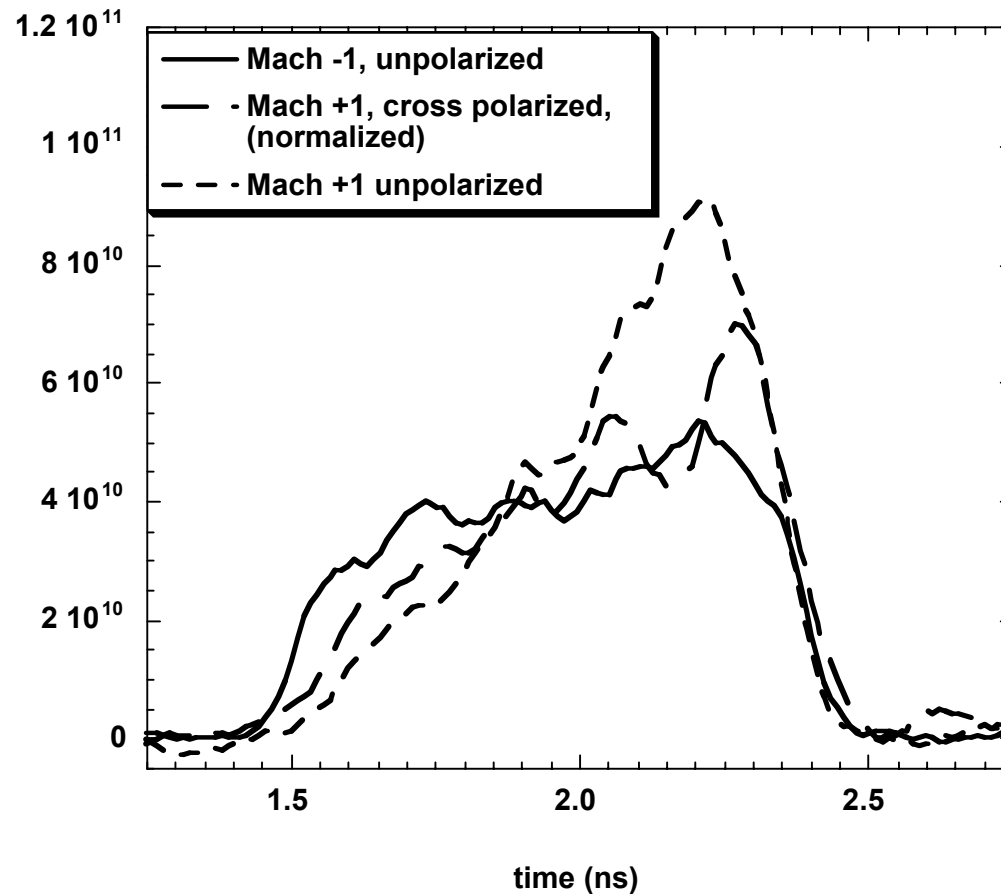


The broad SRS in a gasbag target has similar density and temperature as the LEH plasma in a NIF hohlraum. Laser smoothing has a clear impact on this SRS.

2w SRS scattered fraction



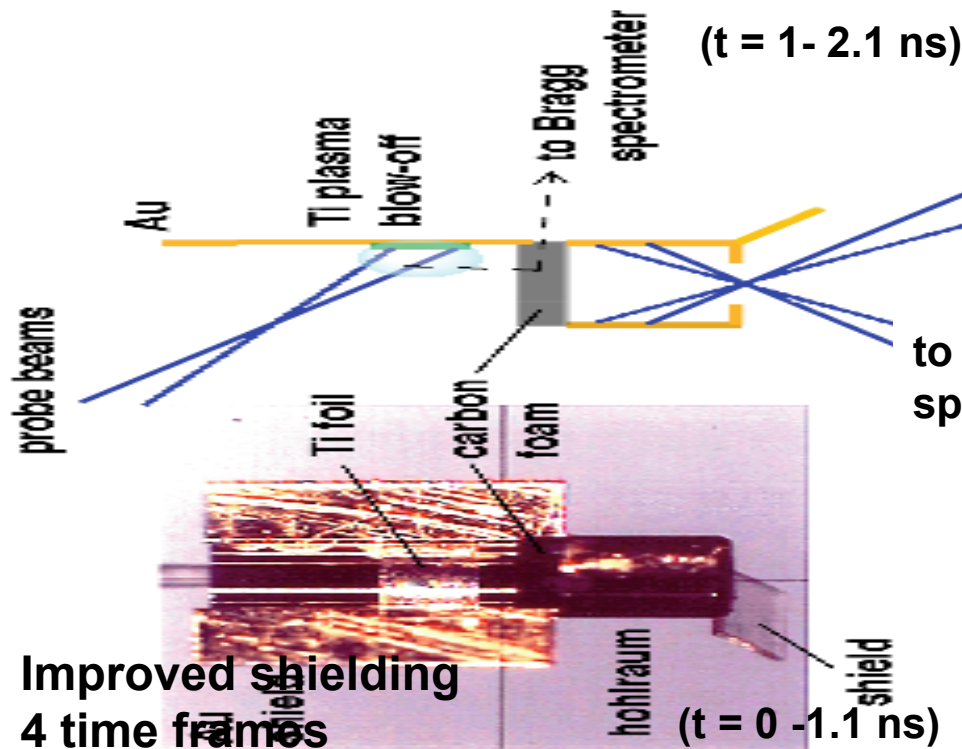
# Transmission of Cross Polarized Component is Less Than Transmission of Amplified Total Power



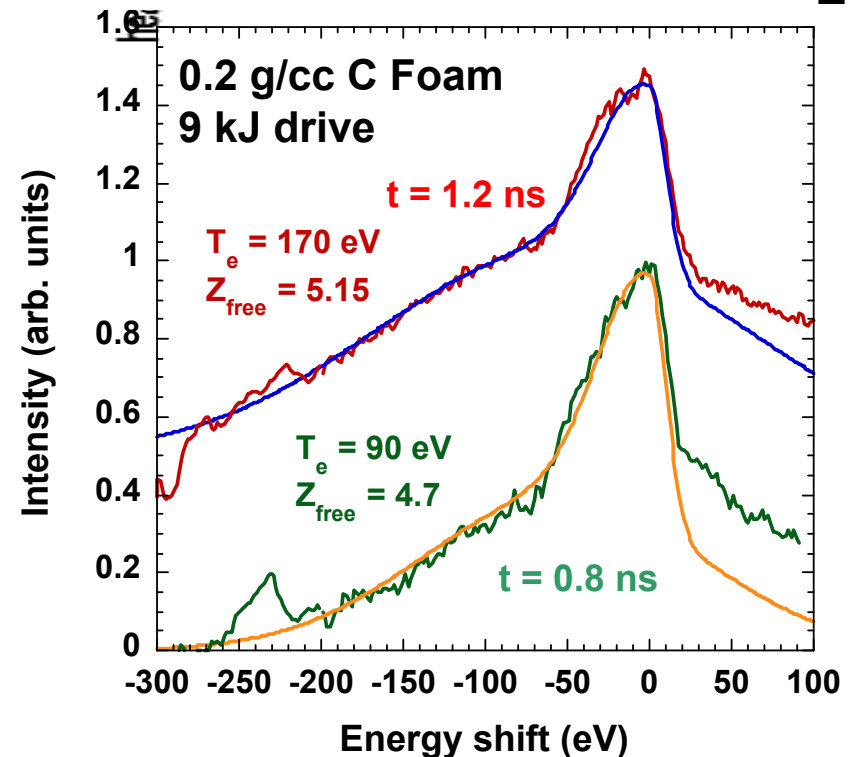
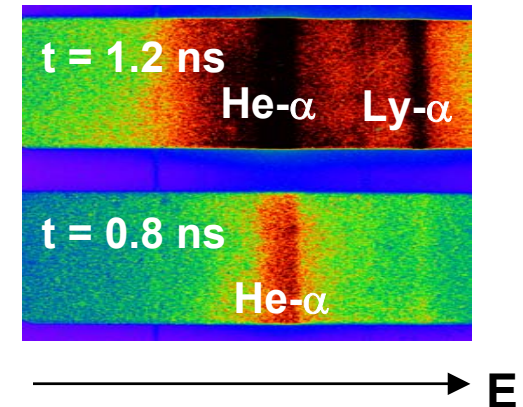
In high intensity CH case amplification relative to Mach -1 is only significant in total power, indicating no significant amplification of cross polarized component.

# Improved x-ray scattering in radiatively driven foams yielded clean time-resolved spectra

**Ablator  
Physics**



to streaked Bragg spectrometer



## Applications:

### Radiation transport experiments

J. Edwards *et al.*, Phys. Plasmas (2000)

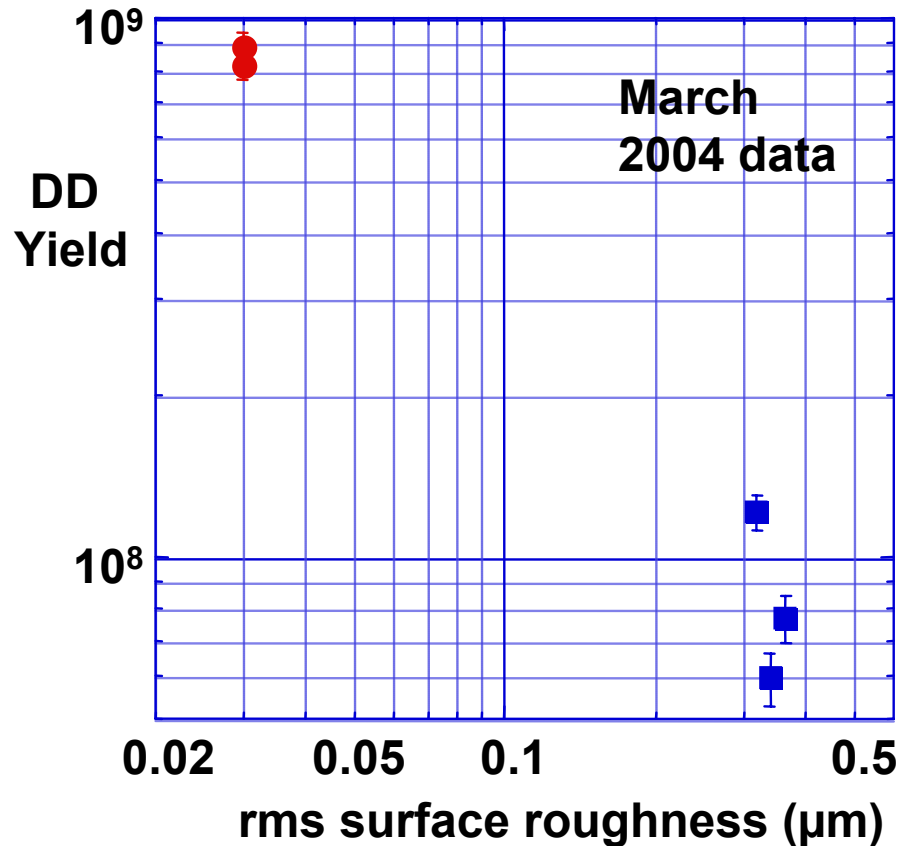
C. Back *et al.*, Phys Plasmas (2000)

### ICF ablator studies

# We have baseline set of Ar-free high CR CH(Ge) implosion data vs surface roughness

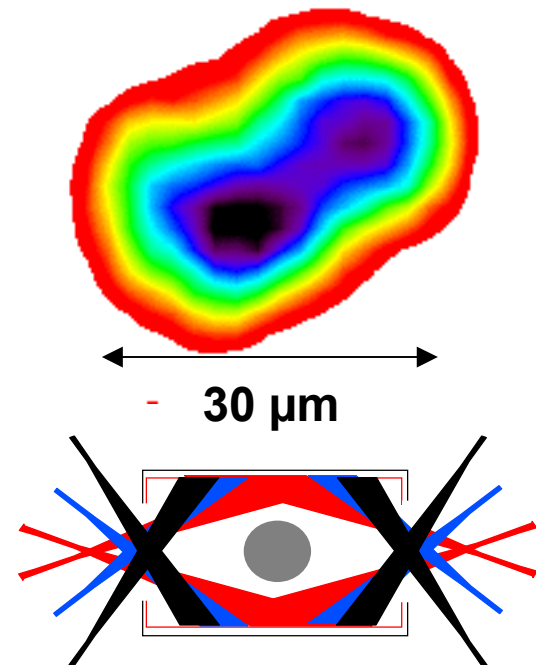
*Implosions*

Yield vs surface roughness for 10 atm.,  
CR = 15 CH(Ge), PS 26 implosions



High contrast ultra-high magnification imaging also demonstrated

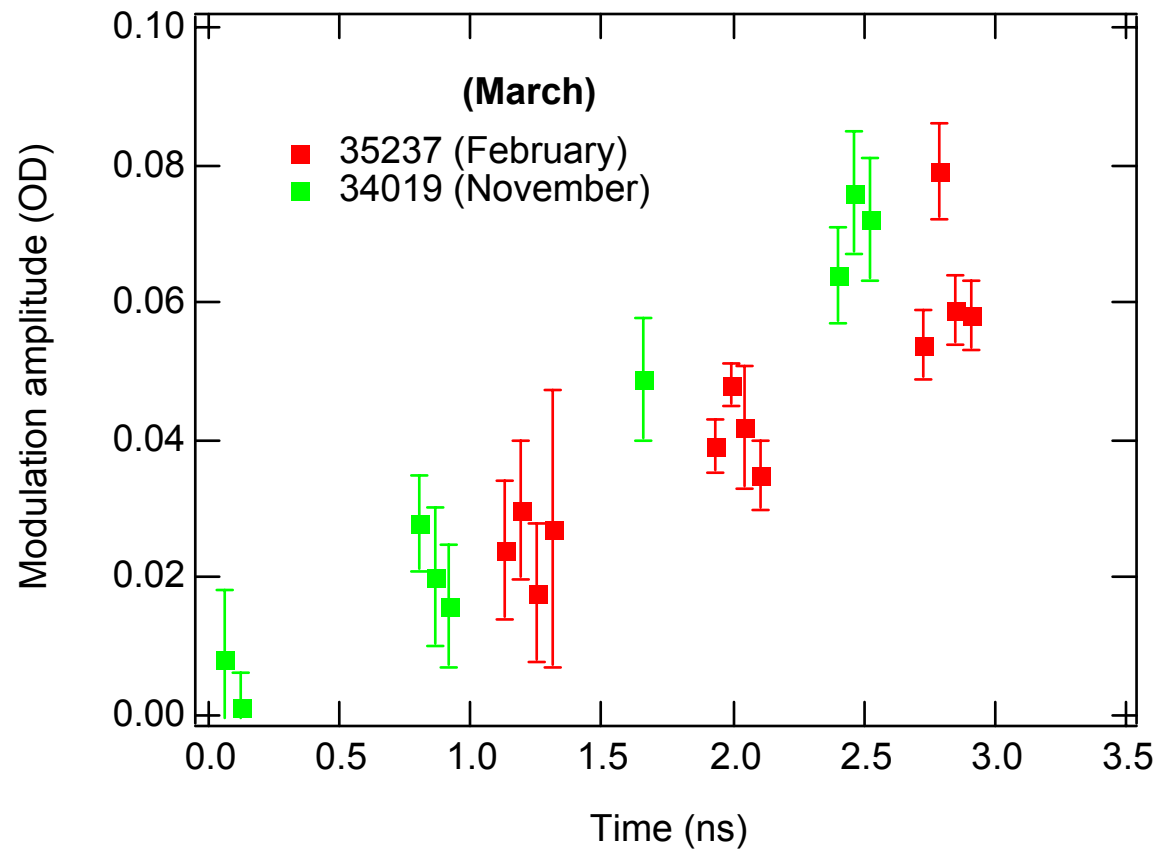
87x magnification x-ray core image



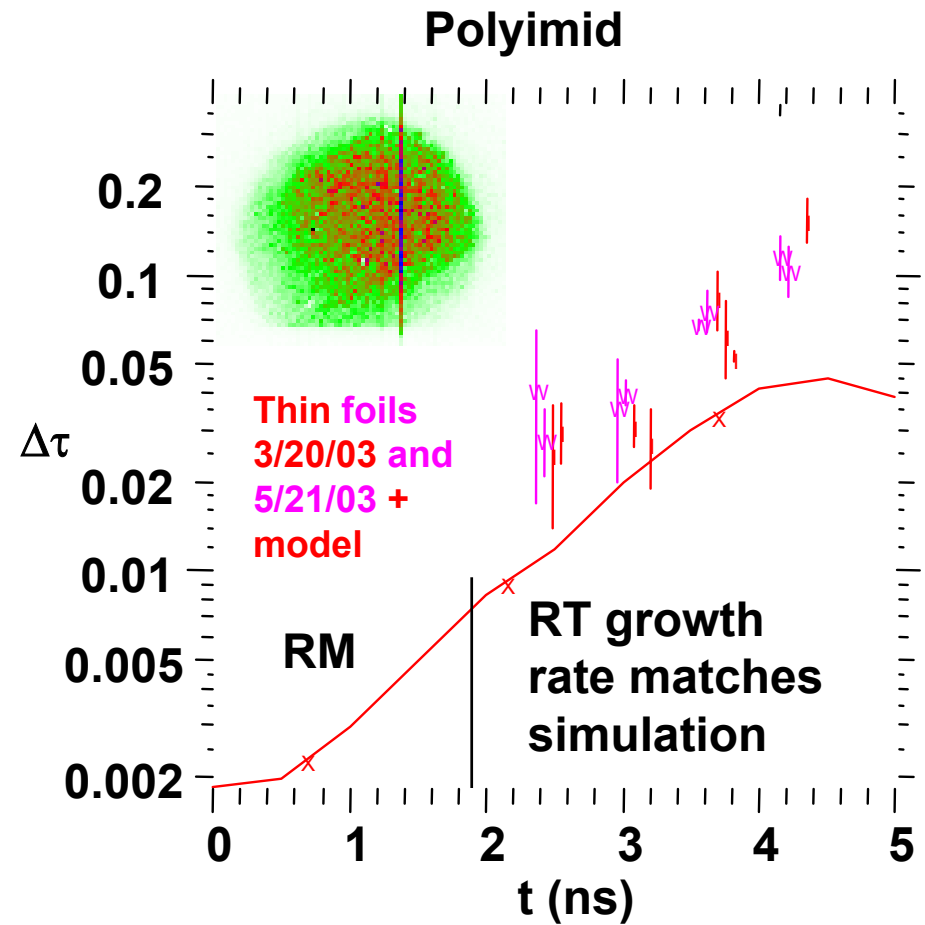
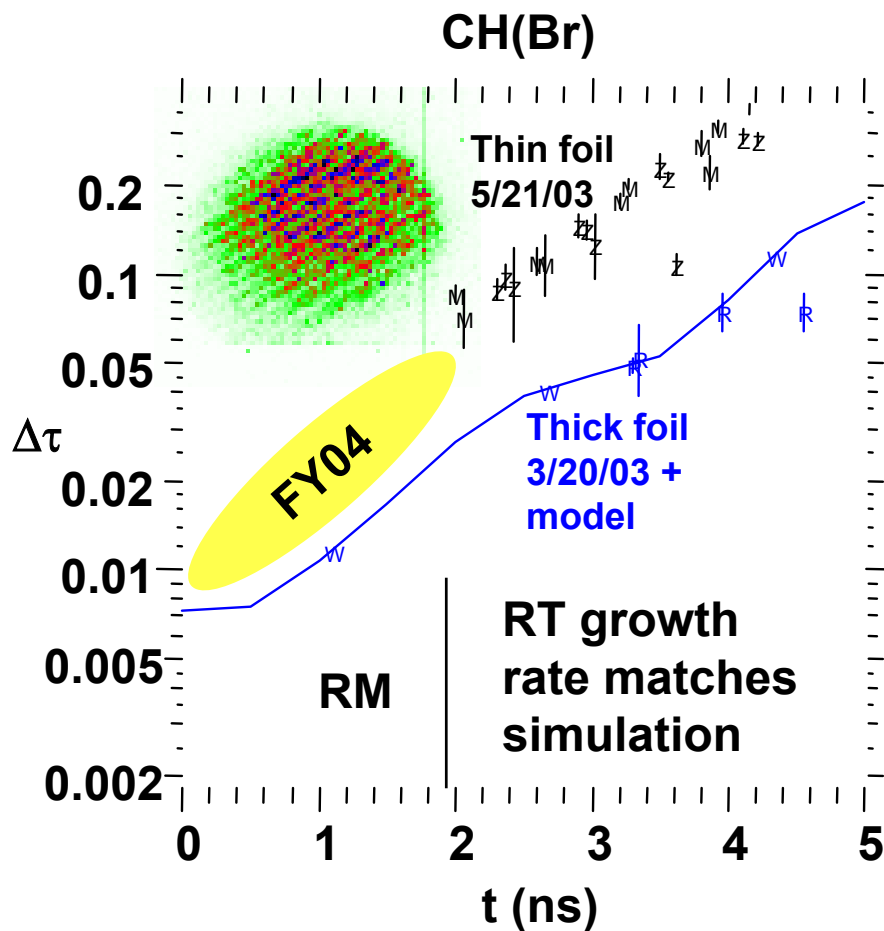
Removal of DPR improved yield and symmetry

PS26 platform will be used for testing other capsule ablators (e.g. Be(Cu))

## PIRT results for FY04 show growth rates similar to previous experiments

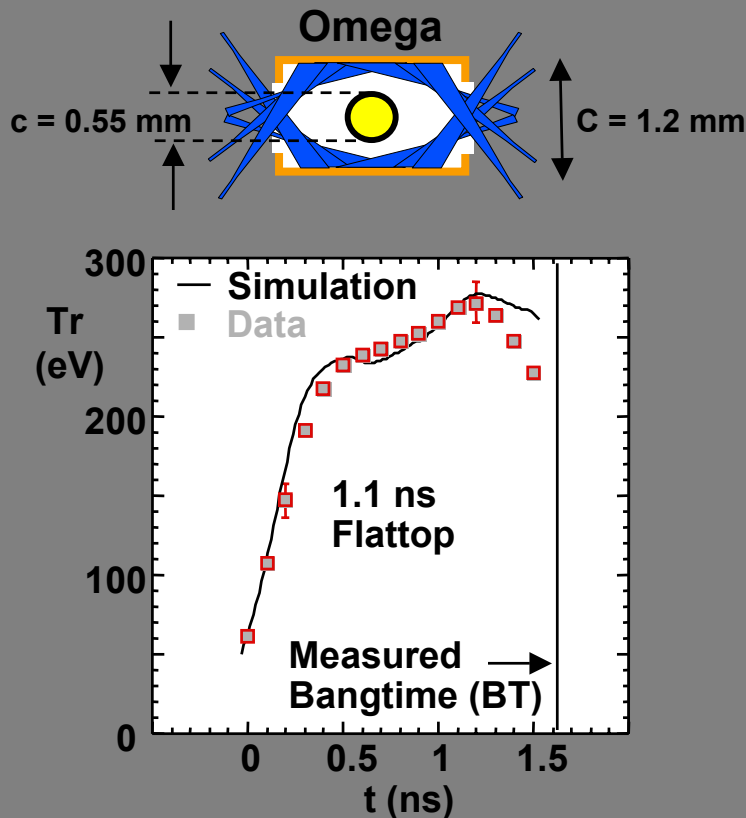


# Thin CH(Br) and polyimid ablators showing repeatable unexpectedly large RM growth phase

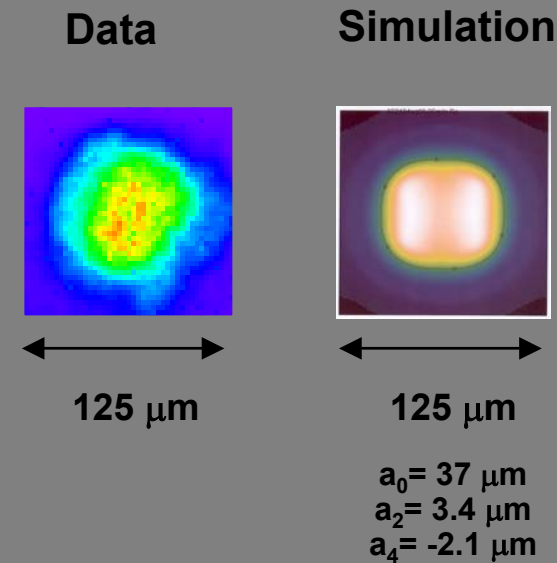


# First enhanced coupling efficiency implosions at NIF-relevant peak Tr gave expected symmetry

DD filled CH(Ge) capsule implosions  
 $C/c = 2.2$  vs. NIF baseline  $C/c = 2.5$

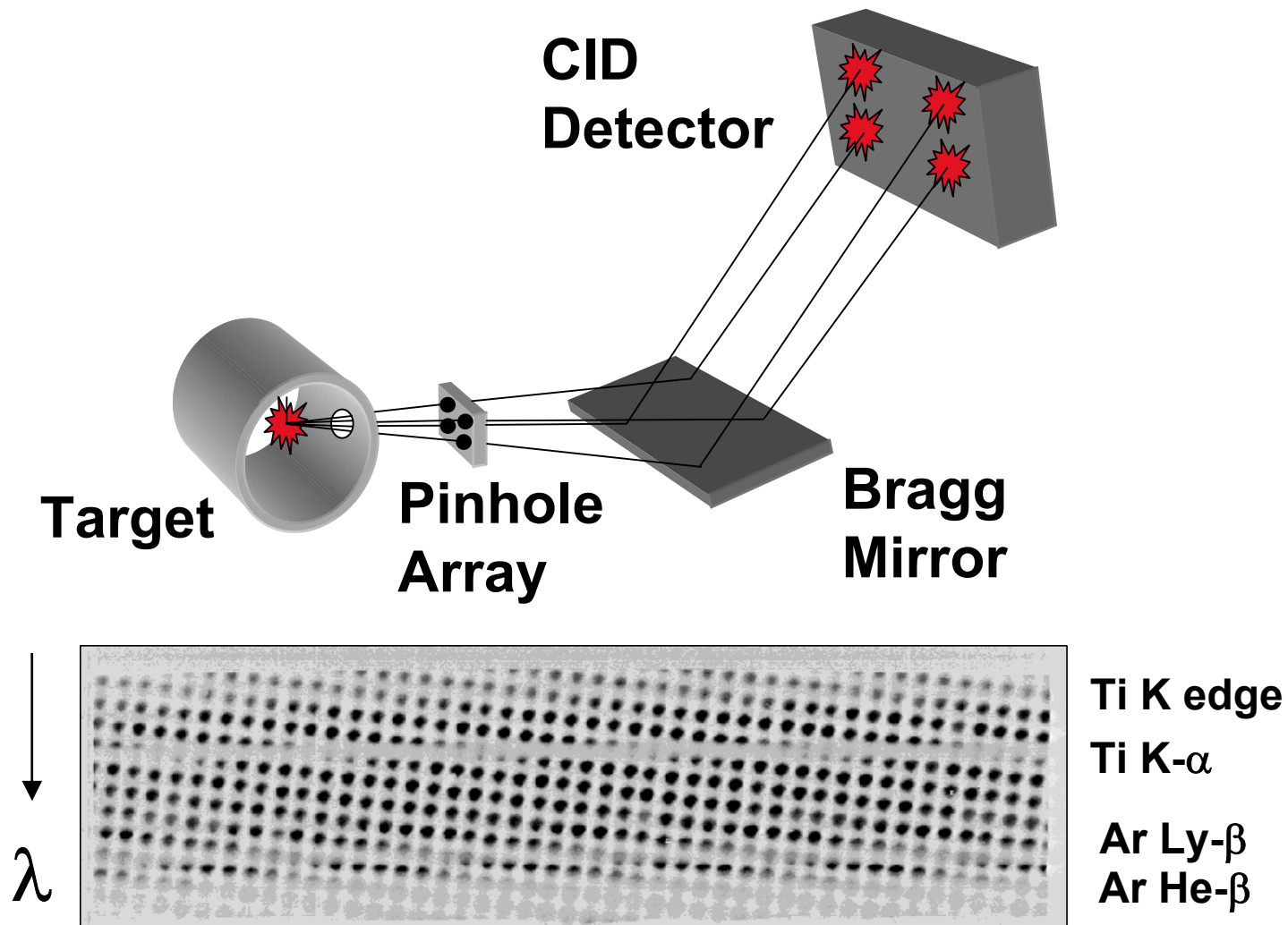


Measured and calculated X-ray core image shapes at BT compare well



Convergence ratio  $\approx 8$

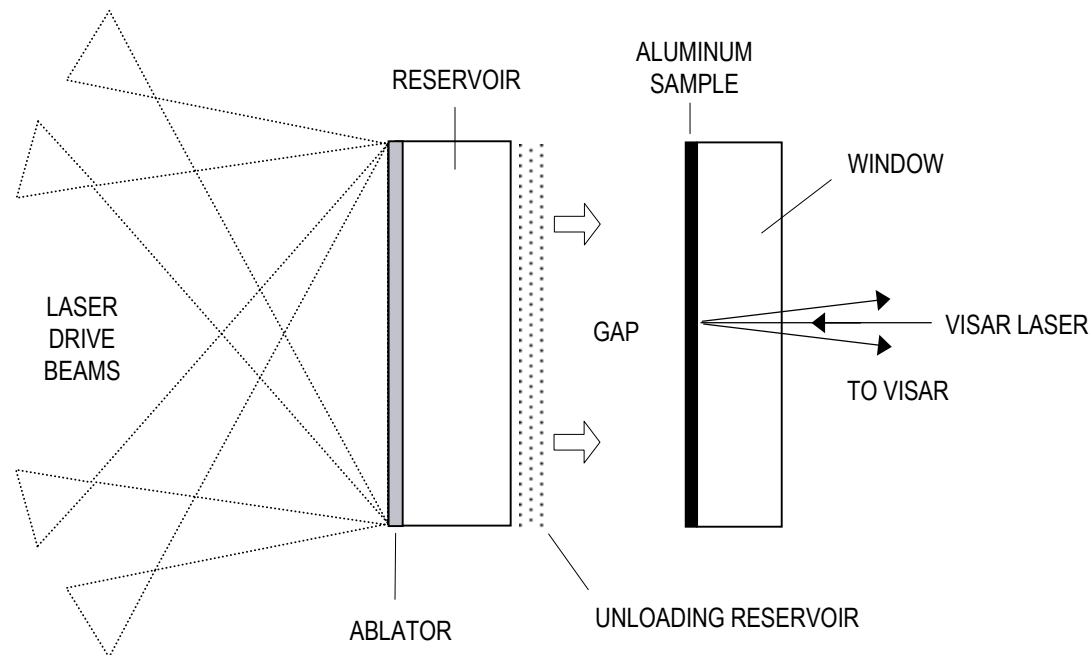
Ongoing work to further improve symmetry and coupling in these high Tr hohlraums using “cocktail” hohlraums



## I-Drive Campaign (Sept. 2003): Demonstrated Loading Dynamics for Laser-ICE in the 1+ Mbar Regime in Aluminum

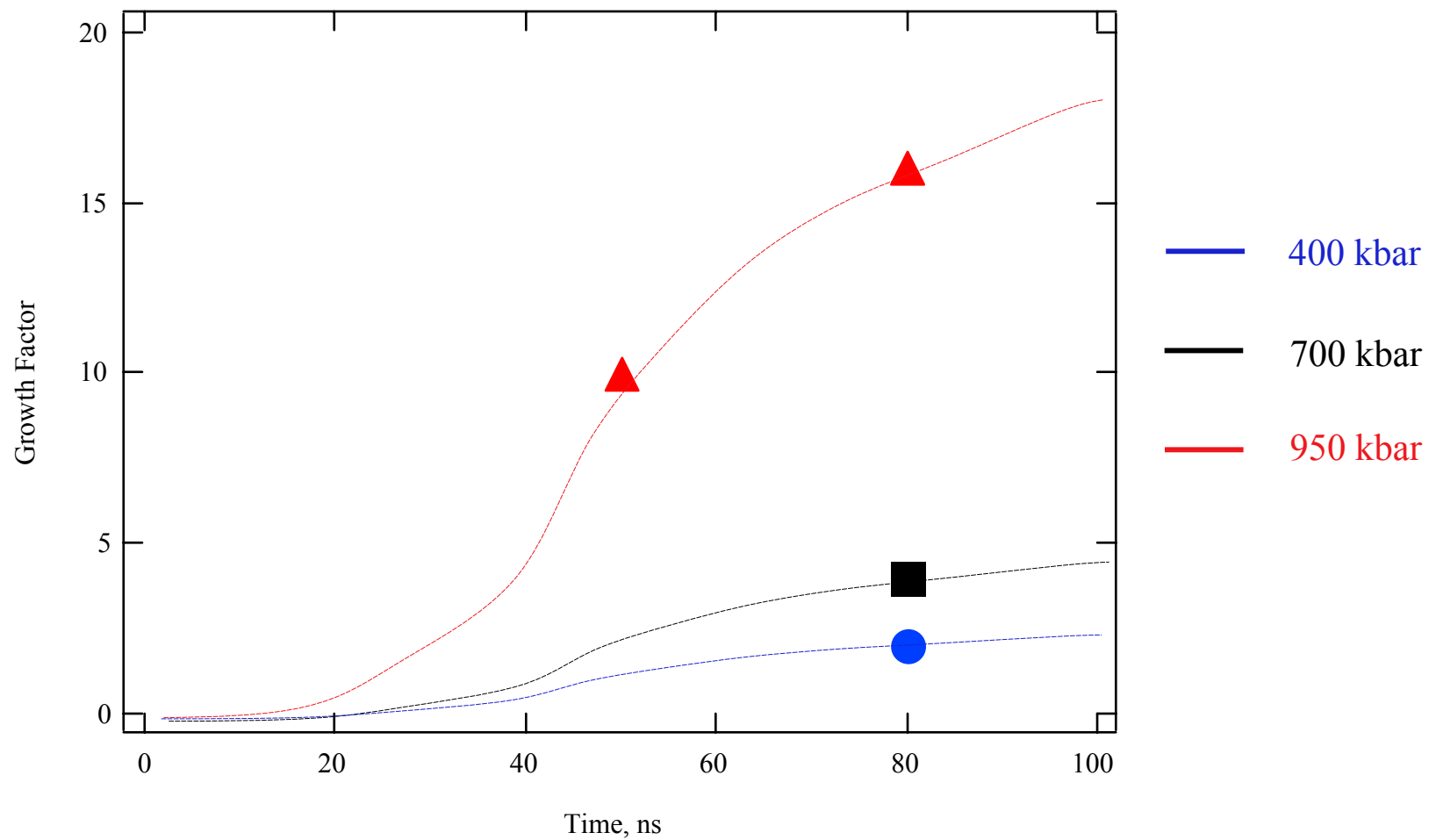
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- July & September campaigns collected VISAR data for Laser-ICE for peak pressures from ~ 0.2 to 2 Mbar.



- Ten beams with SG8 phase plates were used to drive a ~200  $\mu\text{m}$  thick reservoir composed of 12.5% brominated polystyrene across a 300  $\mu\text{m}$  vacuum gap.
- The target consisted of aluminum sputter coated onto a LiF window to avoid glue joints.

- Data was acquired at three peak pressures. We will look at vanadium growth again in August in order to acquire additional data to constrain modeling efforts.



Friday, 6 August 2004 ( $\Omega$ )

## NWET X-ray Source Development

### Targets:

#### Gasbag:

Ar (0.1%) + CH<sub>4</sub> (99.9 %);

p= 0.5 atm

O.D. bag: 2.8 mm

O.D. washer: 4.5 mm

Transmission: > 30%

#### Stopper:

CH foil

Thickness= 100  $\mu$ m

Diameter= 11.5 mm

Distance to gas bag center = 2 mm

Aligned separately, first the gasbag using TIM3 target positioner, then the stopper using H2 positioner.

